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EVALUATION OF THE TROUGH-TYPE RAIN GAGE

Although infrequently used, the trough-type rain gage has been described as aerodynamically the most efficient of gages (Hayes and Kittredge 1949). This applies only to the commercial semicircular eave-gutter type of trough and not to troughs rectangular in cross-section. The latter, as well as the upright cylindrical type of gage, produces greater disturbances in the rain-bearing wind stream.

A major advantage of any type of trough gage is its readily adjustable area of catch. Troughs have been used that range in width from 4 inches to 9 inches and in length from 24 inches to 80 feet. A trough gage 4 inches wide and 12.56 inches long has the same surface area as a standard 8-inch cylindrical gage. Larger troughs with greater areas are particularly useful in throughfall studies, as they can be used to measure a composite of rainfall and drip from a variety of canopy conditions.

Dr. W. C. Lowdermilk apparently was the first to design and install a trough gage—in 1929 in southern California. Trough gages were later examined critically in two comparative rain-gage investigations, both in California (Storey and Hamilton 1943, Hayes and Kittredge 1949). In both investigations trough gages showed up well, probably better than any others, including shielded and tilted gages. But they never caught on.

Experience with Trough Gage

Since 1929 the use of the trough gage has generally been restricted to interception studies, and it was such a study that occasioned this analysis. Our interception studies were begun in 1950 at the Delaware-Lehigh Experimental Forest (Dilldown Watershed) and the Pocono Experimental Forest in northeastern Pennsylvania, using half-round trough gages 6 by 36 inches. These gages were used to measure throughfall under vegetation and rainfall in the open.

In 1952 several Weather Bureau Standard rain gages were placed adjacent to trough gages in the open. To our dismay, it soon became evident that the trough gages were catching less rain than the standard gages. The most obvious explanation for this was that some of the rain splashed out of the troughs. The strong winds accompanying summer storms probably blew away part of the spray from raindrops bouncing on the relatively flat bottom of the trough.

This hypothesis was tested in the summer of 1953. A number of new trough gages were made, having 3-inch vertical sides above the semi-circular cross-section, to contain the splash. A high trough was exposed along with a low trough and a standard gage at several locations. At one location, four additional low troughs were oriented in the four cardinal directions, to detect any effect of direction. During each storm the resident observer noted the prevailing wind direction.

The first test was informative: the catches in the high trough were not significantly different from those in the standard gage, but those in the low trough were significantly less. No effect of direction was apparent. Inadvertently, however, the directional troughs had been placed so that they sloped from 5 to 19 percent. After slope corrections had been applied, a pattern appeared: the greater the slope, the larger the catch of rainfall.

Accordingly the test was rearranged and enlarged in 1954. The directional troughs were all given the same slope (5 percent), and four other low troughs were lined up in one direction (south) with varying slopes. The pattern detected the preceding year was confirmed: no effect of direction of slope but a correlation with percent of slope.

Regressions were calculated, using the following general equation as a model:

$$Y = a + b_1X + b_2XS$$

in which

Y = Amount per storm as measured in the standard gage, in inches.
X = Amount caught in any low trough, in inches.
S = Slope of the low trough, in percent.

Covariance analysis showed no difference between the 1953 and 1954 data; in fact, all three coefficients were essentially identical. Therefore, the data for the 2 years were pooled and the following equation was calculated:

$$Y = 0.011 + 1.073X - 0.00319XS \tag{1}$$

Both variables were highly significant at the 1-percent level. This equation will be used to correct trough-gage measurements (in the open) for a forthcoming paper on interception.

Why The Discrepancy?

The reader may wonder why the results of these analyses do not agree with the findings of earlier investigators. In both studies (Storey and Hamilton 1943; Hayes and Kittredge 1949) trough gages gave an excellent measure of rainfall. A reasonable explanation for the discrepancy is available.

In both earlier studies the terrain was steep: Rain Gage Hill, the site of the 1943 study, has slopes ranging between 30 and 40 percent, according to Hamilton (1954); the area for the 1949 study, in Strawberry Canyon, was a 40-percent slope. And in both studies the troughs were placed parallel to the slope. But in our studies the terrain was nearly level and the troughs sloped only enough to provide drainage. The trough slopes, measured so that corrections could be calculated, ranged between 5 and 20 percent.

At these low slope angles, some of the raindrops would either bounce and splash out or be blown out of the trough. When raindrops hit a sloping surface, however, they do not bounce vertically; instead they are deflected into the trough. This explanation is reinforced by Equation 1: the XS interaction accounts for the slope effect. For example, a catch of 3.00 inches in a trough sloping at 5 percent results in an estimate of 3.17 inches of actual rainfall. On a 20-percent slope, the estimate is 3.03 inches. If the equation were extrapolated to a 25-percent slope, there would be little or no difference between the actual catch and the estimated catch. In other words, if the trough slopes 25 percent or more, its catch provides an accurate measure of rainfall. This probably explains the accuracy of the gages in the California studies.

Trough Gages Under a Canopy

A further study was made to determine if our throughfall trough gages had been catching an accurate sample. At the Pocono Experimental Forest, in large pole-size northern hardwoods, six positions for throughfall troughs were established. High troughs were set in three positions and ordinary low troughs in three others. A new arrangement of the troughs was randomly made after each storm.

A similar series of positions was selected for throughfall testing in scrub oak at the Dilldown Watershed. Here the troughs could not be moved readily, so three splash guards were fabricated to set on the ordinary trough gages and to simulate high troughs. After each storm the splash guards were moved to a randomly selected new arrangement.

The results were inconclusive. In the high forest, no significant dif-

ferences were found between the high-trough and low-trough catches. In the scrub-oak area, however, some of the positions showed significantly higher catches when the splash guards were installed. In view of the fact that rain dripping from a high forest canopy did not splash out of the troughs, it seems doubtful that drip from low scrub-oak cover could have been lost. We suspect that the splash guards bulged enough to make a greater catch area than we measured.

Conclusions

The conclusions to be drawn from this study can be stated in words of caution. The trough gage, although aerodynamically efficient, may allow a part of the rain to splash and be lost unless the gage is sloped more than 25 percent. If such slope cannot easily be maintained, other means must be taken to prevent or contain the splash. It can be contained by built-up sides, but at the expense of aerodynamic efficiency.

Another idea, although not tested, is to use a V-shaped trough rather than a semicircular trough. The bottom angle of the V should be between 90° and 120°. As there are no horizontal surfaces, the drops could not bounce vertically, and there should be no splash from the sloping sides of the V.

One other caution: the sides of the trough gage are relatively flexible, and this flexibility affects the surface area of the orifice. If this area changes or cannot be measured accurately, the sample will be in error. Some type of reinforcing should be added to the long sides of a trough gage.

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